Based on Longship:

Potential for Cost Reductions in the CCS Value Chain

External Report by Gassnova SF 06/2025

GASSNOVA

Summary

Carbon capture and storage (CCS) projects face significant challenges in the coming years, particularly in ensuring construction and operation within acceptable timeframes and cost limits. To meet the expectations of investors, authorities, and society at large, it is essential to reduce the costs of future CCS facilities. Identifying cost reduction drivers is key to the role of CCS technology in cutting global carbon emissions.

By analysing cost drivers such as technology readiness, regulatory maturity, and industry practices, Gassnova aims to highlight the potential for more cost-effective solutions.

Longship has provided valuable insights into cost drivers throughout the CCS value chain. The project has revealed important technological and operational challenges. At the same time, the covid pandemic and geopolitical events have impacted project progress and led to unforeseen costs compared to original estimates.

The experiences from Longship point to the potential of regulatory changes and adjustments to industry practices tailored to CCS-specific requirements. The findings show, among other things, that technology maturity and the choice of integration solutions between emission sources and capture facilities are critical to achieving cost-effective outcomes.

Capacity increases and technological advancements can lower the cost per tonne of captured CO_2. This may support broader implementation of CCS in Norway and strengthen the global development of carbon capture and storage technology.

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Gassnova SF, 6 June 2025

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1. Introduction

Over the next decade, carbon capture and storage (CCS) projects globally will face significant challenges in completing construction and operations within acceptable time and budget constraints. To meet the demands of investors, authorities, and society at large, it is essential to reduce the costs of future CCS facilities. The purpose of the Longship project is to demonstrate that the CCS value chain is both safe and feasible. At the same time, Longship is intended to facilitate learning and cost reductions for subsequent CCS projects. Longship comprises Heidelberg Materials' (HM) capture project "Brevik CCS", Northern Lights Joint Venture's (NL JV) transport and storage project "Northern Lights" (NL), and Hafslund Celsio's capture project "Oslo CCS".

Over several years, Gassnova has developed detailed and unique knowledge of the CCS value chain. This has taken place through its follow-up of Longship – from early-phase planning through Front-End Engineering Design (FEED), into the construction phase, and planning for operational follow-up. In addition, CLIMIT[1] has supported several projects that have been crucial for technology development across the entire CCS value chain. TCM[2] has also contributed to essential knowledge development ahead of Longship by advancing the amine process to commercial scale maturity. The results from Longship contribute to technology development by supporting research, development, and innovation in the CCS field. The project outcomes focus on more tailored standards and regulations, which may, among other things, strengthen the development of the supplier market within CCS.

Conducting detailed analyses of cost drivers and potential cost reductions is a comprehensive task. This report highlights the cost drivers with potential for cost reductions, based on Gassnova's knowledge of the Longship project. The analysis considers Brevik CCS and NL – but not Oslo CCS. It is based on the first phase of Longship, and the work was carried out from May to November 2024. Gassnova extends its sincere thanks to Brevik CCS and NL for their valuable contributions to this work. Gassnova's main objective is to promote technology development and capacity-building for cost-effective and future-oriented solutions for CO_2 management. To date, Gassnova has published two external reports presenting Technical[3] and Regulatory Lessons-Learned[4] from Longship.

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[1] The CLIMIT Project Database: Prosjekter Archive - Climit

[2] TCM: 18 Years of public-private partnership for developing post-combustion CO2 capture at Technology Centre Mongstad in Norway by Gelein De Koeijer, Erik Gjernes, Steinar Pedersen, Carsten Ehrhorn, Stephane Jouenne, Veronique Pugnet, Renaud Cadours, Svein Ingar Semb, Muhammad Ismail Shah :: SSRN

[3] Gassnova: Technical Learning Report: Developing Longship - Key lessons learned - Fullskala

[4] Gassnova: Regulatory Learning Report: Regulatory Lessons Learned from Longship – The public sector's involvement in Europe's first industrial CCS chain - Fullskala

2. Costs of the Longship Project

The Longship project is a large and costly initiative, with the state providing most of the funding. The individual participants in Longship are responsible for implementing their respective parts of the project. The state has entered into separate state aid agreements with each of the Longship participants – specifically HM and the NLJV. These agreements regulate, among other things, the distribution of costs between the state and each participant.

Carbon capture and storage requires that the entire value chain – from capture to storage – is operational simultaneously. In a demonstration project involving new technology, this introduces additional uncertainty. Through the state aid agreements, the government mitigates the risk for the participants in case other parts of the value chain do not progress as expected. The project does not include bilateral agreements between the participants.

The total cost of the project was estimated at NOK 25.1 billion (in 2021 currency) at the time of the investment decision. The overall management framework (P50) for the state was NOK 16.8 billion, as presented in White Paper No. 33 (2019–2020)[5] and the KS2 report from the external quality assurers Oslo Economics and Atkins in 2020[6]. This amount included both investment and ten years of operations for all three participants in the project.

This report focuses on the two parts of the project that have progressed the furthest: Brevik CCS and NL.

The agreements stipulate that for HM, 100% of the investment costs are covered up to approximately NOK 1.2 billion, and 75% of investment costs beyond this amount are covered, up to a defined maximum limit. For the NLJV, 80% of the base investments and 50% of specifically defined additional investments are covered. Similarly, the state covers between 75% and 100% of specifically defined eligible operating costs for a period of ten years, up to a specified maximum limit.

The costs associated with Longship must be viewed in the context of it being a demonstration project. One of its key objectives is to facilitate cost reductions for subsequent projects, in part through learning and technology development generated by the project.

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[5] White Paper No. 33 (2019–2020) *Longship – Carbon Capture and Storage* Meld. St. 33 (2019–2020) - regjeringen.no

[6] Oslo Economics, Atkins: kvalitetssikring-ks2-av-tiltak-for-demonstrasjon-av-fullskala-co2-handtering.pdf, 24.06.2020

Figure 1 is taken from the White Paper Longship – Carbon capture and storage from 2020[5], and shows, among other things, DNV's assessment of how the costs of carbon capture and storage – measured as mitigation cost per tonne of CO_2 – may develop[7], as more facilities are built and the total volume increases.

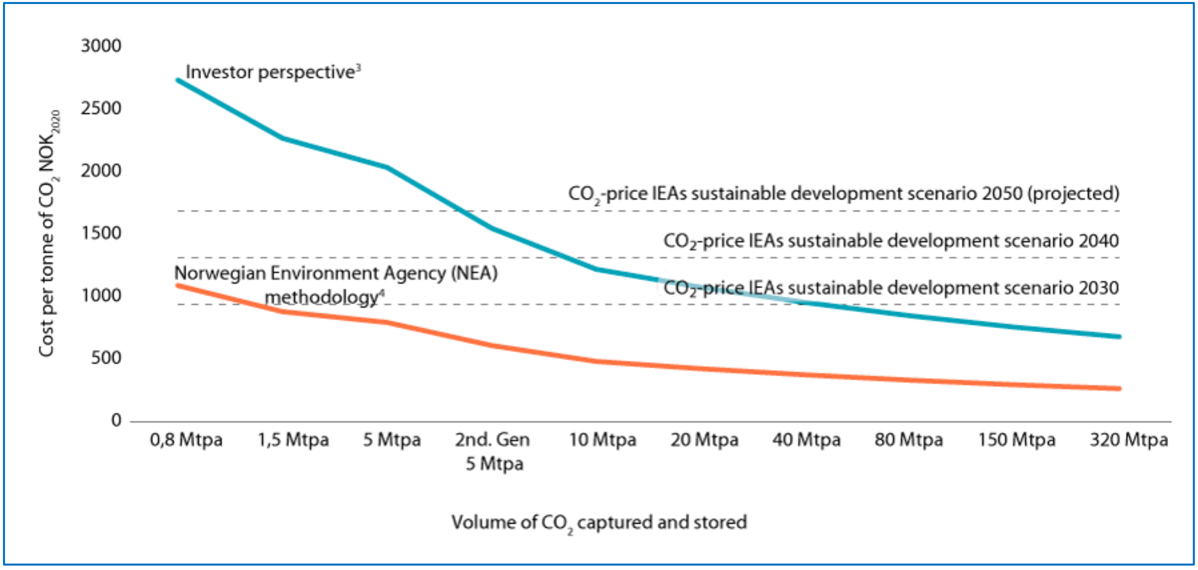

Figure 1 Expected Development in Average Mitigation Costs for the CO_2 Management Project.[5]

In this report, the focus is on the total costs of the project and its components, rather than the distribution of cost shares between the state and other stakeholders. The total cost is a natural starting point for cost overviews and drivers in CCS projects, in addition to the assessment of potential cost reductions and optimization.

At the time of the investment decision presented in the Proposition 1 S (2020–2021)[8] State budget for 2021, the investment budget for Brevik CCS was estimated at NOK 3.2 billion. The corresponding investment estimate for the NL project was NOK 9.1 billion, including both base and additional investments. Annual operating costs were estimated at NOK 119 million for Brevik CCS and NOK 477 million for NL.

Costs have increased during the construction period due to both project-specific factors and general economic developments marked by extraordinary events. The construction phase of the Longship project has taken place during a turbulent time. The covid pandemic, subsequent containment measures, and Russia's war in Ukraine have all had a significant impact on project

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[7] From an investor perspective, a real discount rate of 8% has been applied to both CO_2 volumes and costs over a 25-year lifetime. According to the methodology of the Norwegian Environment Agency, a real discount rate of 4% is applied to costs over a 25-year lifetime, while CO_2 volumes are not discounted.

[8] Prop. 1 S (2020–2021): Other Authorisations XVI – Authorisation to enter into agreements and commit the state to obligations for Longship (carbon capture and storage).

implementation[9]. These events led to limited access to labour and raw materials and resulted in fluctuating prices for raw materials and energy. High steel prices are one example of cost increases that affected the project. Bottlenecks and shortages, rising prices for key input factors, and economic stimulus measures contributed to price increases in other goods and services as well. From 2020 to 2024, the average price increase was 19%.

During the construction period, two supplementary quality assurance reviews were conducted – in 2022 and 2023 – which, among other things, examined the reasons for the cost increases. In the 2022[10] supplementary quality assurance, it was noted that HM's expected costs had increased by approximately NOK 850 million compared to the KS2 assessment in 2020. The quality assurer cited several reasons for this increase, including overconfidence in the project's maturity at the time of KS2, an underestimation of the project's complexity, a lack of familiarity with conditions at the Brevik facility, as well as costs related to covid and rising market prices. The covid-related impact was estimated at between NOK 70 and 120 million, depending on whether increased material prices were considered a covid-related effect.

In the 2023[11] supplementary quality assurance, changes in price levels, a reduced uncertainty allowance, and extraordinary additional costs – at least partially due to Russia's invasion of Ukraine and the subsequent sanctions against Russia – were highlighted as causes of cost changes at Brevik CCS. The quality assurer assessed that NL appears to be staying within previously estimated expected investment costs when price inflation is considered.

In 2023, the state and HM entered into an agreement whereby HM committed to completing the project and covering the increased costs, in exchange for being allowed to retain a larger share of the potential return from the project. The state, in turn, committed to providing a start-up grant of up to NOK 150 million.

In Chapters 3 and 4, where capacity scaling and cost drivers are assessed, the Longship investment is divided into five categories. "Brevik CCS" is split into "Integration" and "Capture, Compression & Intermediate Storage", while the base investments in NL are divided into "Transport Ships", "CO_2 Receiving Terminal" and "Permanent Storage".
Budget forecast for investment costs as of autumn 2024 is divided accordingly:

- *Integration:* Includes all budget items for Brevik CCS, except those covering the capture plant, compression and intermediate storage, as well as heat exchangers connected to the cement plant; amounts to NOK 2.2 billion
- *Capture, compression & intermediate storage*: Covers the capture plant, compression and intermediate storage, as well as heat exchangers connected to the cement plant; amounts to NOK 2.7 billion

[9] Burns, A., Gomez, Y.D. "Lessons learned in the design and construction of the Brevik CCS facility," GHGT 17, October 2024

[10] Oslo Economics, Atkins: supplerende-kvalitetssikring-av-langskip-fangst-og-lagring-av-co2.pdf, 11.02.2022

[11] Oslo Economics, Atkins: supplerende-kvalitetssikring-av-norcem-og-langskip-mars-2023.pdf, 30.03.2023

- *Transport ships:* Amounts to NOK 1.3 billion
- *CO_2 receiving terminal:* Amounts to NOK 2.8 billion
- *Permanent* storage*:* Amounts to NOK 4.1 billion

Figure 2 shows the distribution of the Longship investment according to this categorization.

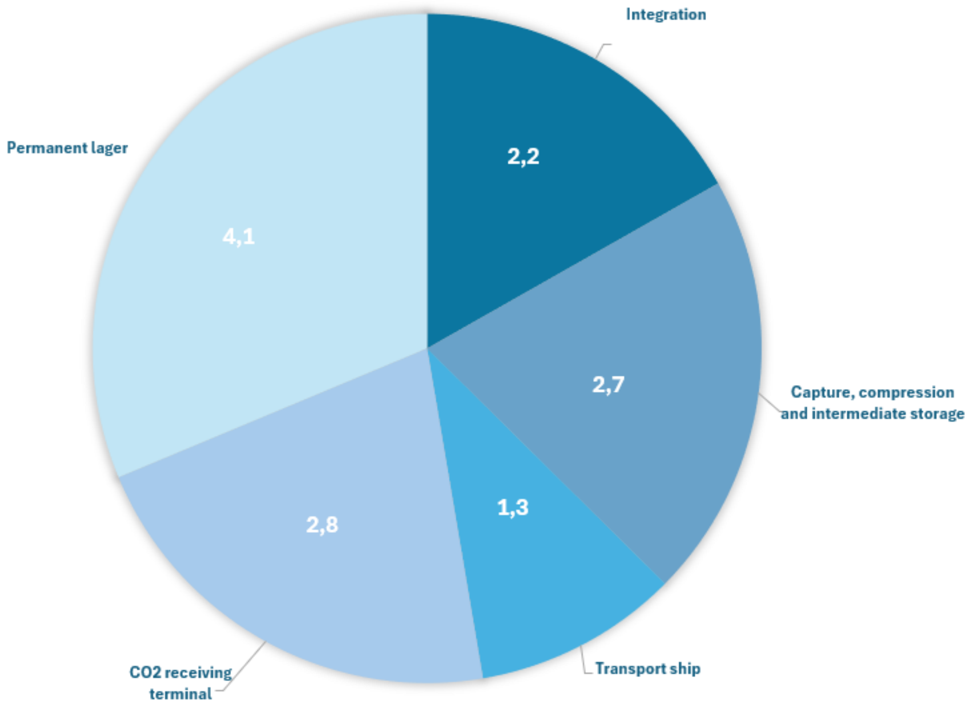

Figure 2 Total investment including base investments for Longship, distributed in accordance with the value chain. The figures in the pie chart represent NOK billions for each category, totalling NOK 13.1 billion.

3. Capacity Scaling of the CCS Value Chain

In autumn 2024, Longship consists of a full-scale CCS value chain originating from HM's cement production facility in Brevik, which emits 0.8 million tonnes of CO_2 per annum (tpa) from flue gas with a CO_2 concentration just below 20%. The availability of waste heat from the cement production and the capture plant has determined the capture facility's capacity of 0.4 million tpa CO_2. In addition, Longship includes infrastructure consisting of two ships, a CO_2 receiving terminal at Øygarden with planned overcapacity, and an oversized transport pipeline leading to a permanent storage site.

Figure 3 presents an estimate of how the project costs for Longship are distributed across five different elements of the Longship chain: just over 15% is attributed to integration with the cement plant, around 20% to the capture plant, compression, purification, and intermediate storage in Brevik, approximately 10% to NL's two ships, just under 25% to the NL's receiving terminal, and around 30% to NL's permanent CO_2 storage site.

The figure also illustrates how capacities vary across the different elements in the chain. The cement plant emits 0.8 million tpa CO_2. Of this volume, 0.4 million tpa CO_2 is captured and transported by ship to Øygarden. NL's receiving terminal can be filled with volumes up to 1.5 million tpa CO_2 from new customers, and the CO_2 pipeline to the permanent storage site – designed for 5 million tpa – provides additional overcapacity for future expansion phases.

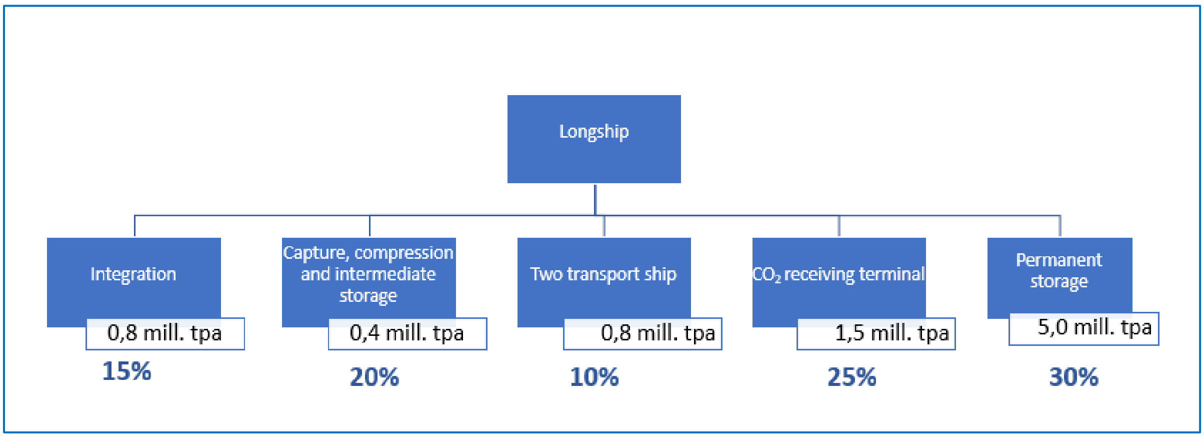

Figure 3 Distribution of investment costs for Longship with varying capacities for each category.

A theoretical normalization of the investment costs for the entire Longship value chain to a mass-balanced capacity of 1.5 million tonnes of CO_2 per annum (tpa) can more clearly illustrate which parts of the value chain are the most cost-intensive per tonne of CO_2.

Such a value chain would require approximately four capture plants with the same capacity and investment costs as Brevik CCS, four ships, a receiving terminal like the one at Øygarden, and an additional well for the geological storage site.

In the analysis presented in Figure 4, the cost forecasts from Longship are used for the five main elements of the full CCS chain, scaled up to a capacity of 1.5 million tpa CO_2. Adding more capture plants leads to a significantly higher need for investment in the chain compared to Longship. Doubling the shipping capacity does not impact the cost distribution to the same extent, and the percentage share remains roughly at the same level as before. The cost share for infrastructure related to the receiving terminal and storage site is significantly reduced.

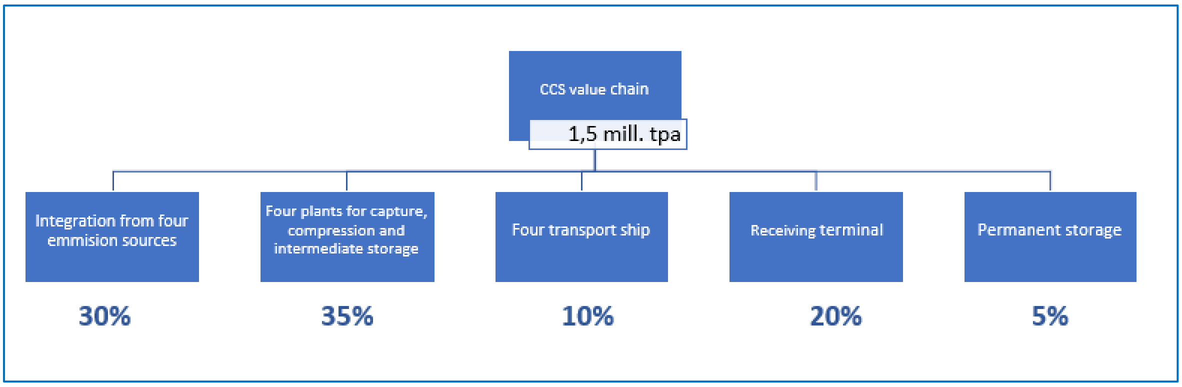

Figure 4 Distribution of investment costs for a theoretical CCS value chain with a capacity of 1.5 million tpa for each main element.

It is interesting to observe in this mass-balanced upscaling, compared to Longship, that the cost centre shifts from the CO_2 infrastructure to the capture plant integrated with the emission source.

In the Longship project, 65% of the project costs are attributed to infrastructure, whereas in the mass-balanced CCS value chain, the infrastructure share is reduced to 35%, and the share related to capture plants integrated with the emission sources increases from 35% to 65%.

The capacity scaling highlights the importance of advancing research, innovation, and other efforts related to the capture process – so that capture plants can become simpler and more cost-effective to build and integrate, both with the emission source and with the transport solution toward permanent storage.

4. Cost Drivers in the Longship Value Chain

The analysis aimed at identifying overall cost drivers and potential cost reductions in the CCS value chain, combines a value chain analysis with a cost driver assessment based on the Longship project.

Longship's value chain consists of five main elements, as shown in Figure 5. The capture project, Brevik CCS, is divided into two parts: the first element represents the integration with HM's cement production facility, while the second is the capture plant itself.
The capture plant comprises the capture process, conditioning facility with compression and purification, and intermediate storage and ship loading equipment.

NL's infrastructure project consists of ship transport from HM's terminal in Brevik to the CO_2 receiving terminal in Øygarden. This CO_2 receiving terminal is the fourth element of the value chain and includes a quay, storage tanks, and CO_2 injection pumps. The final element includes a 100 km pipeline and injection wells to permanent storage.

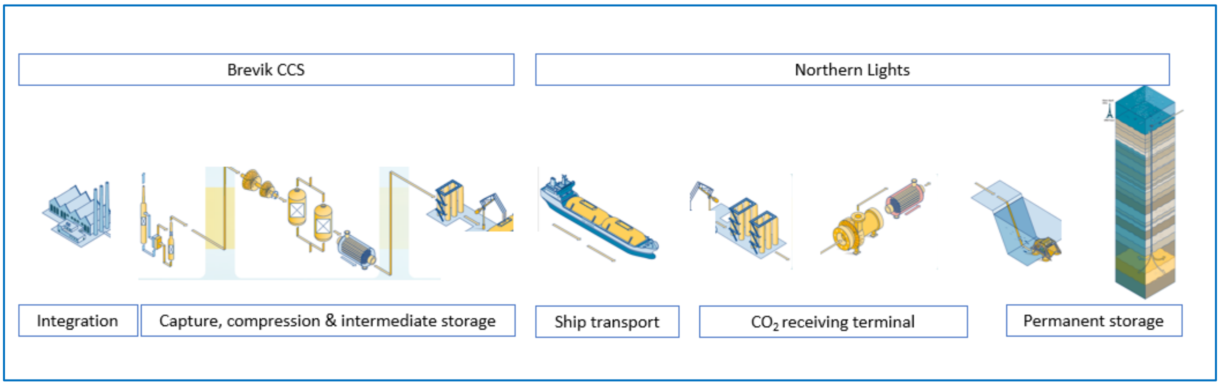

Figure 5 Longship value chain.

Based on Gassnova's experience from Longship through follow-up of the project's construction phase, the most central cost drivers have been identified as:

- *Technology maturity*
- *Supplier-market maturity*
- *CCS-specific procurement expertise*
- *Suitable contract models*
- *Maturity of regulations*
- *CCS Standards / Industrial practices*
- *Economy of scale*

To gain an overview of which elements can contribute to cost reductions in the CCS value chain, a matrix has been developed where the process elements in the value chain form the columns and the key cost drivers form the rows.

For each cost driver, the same question is posed for all process elements in the value chain. These questions highlight the most important issues associated with the given cost driver. The intensity of the responses is graded on three levels – red, yellow, and green – where red indicates the cells with the greatest potential for cost reductions, and green the least.

This traffic light analysis, shown in Figure 6, reveals significant opportunities for cost reductions in the CO_2 value chain. At the same time, the risks and challenges vary considerably across the different stages of the value chain.

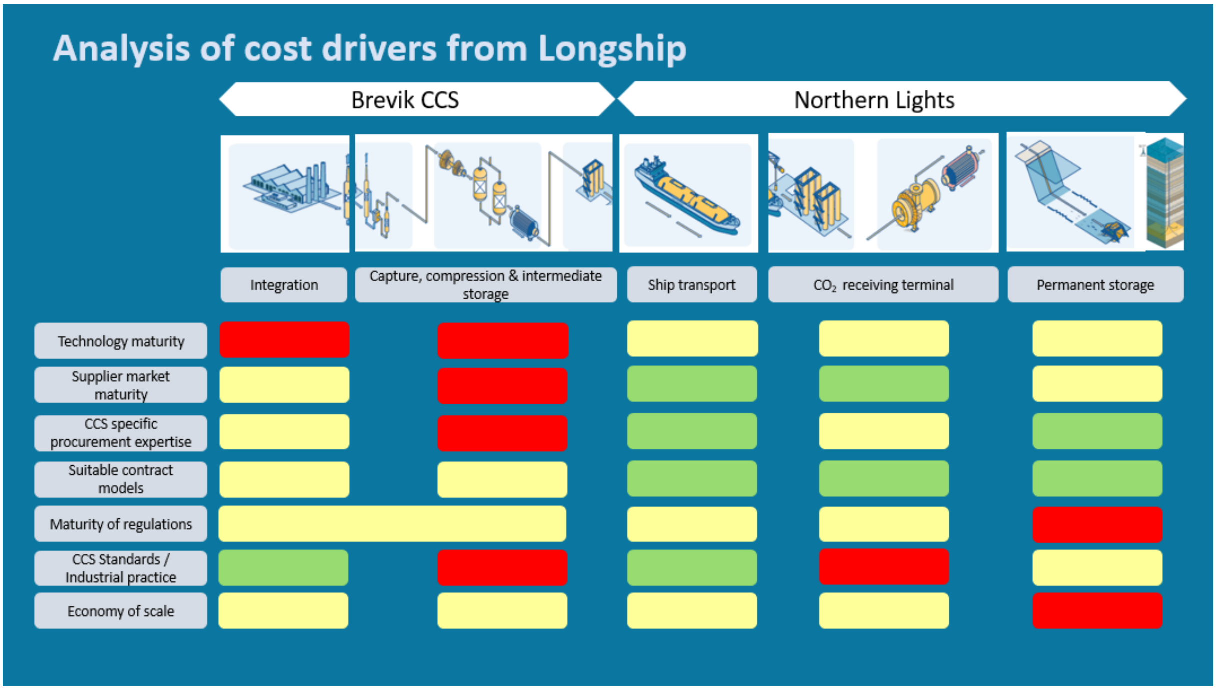

Figure 6 Summary of traffic light analysis for cost drivers in the Longship value chain.

Questions related to the various cost drivers across the entire Longship value chain and corresponding coordinated responses are described below.

Technology maturity: Is the technology mature?

Technology maturity varies across the CO_2 value chain. Integration, capture, compression, and intermediate storage are rated red, indicating that the technology is immature and this part of the chain is expected to have significant potential for cost reduction. This is due to several FOAK (First-of-a-Kind) solutions being involved. Challenges include heat exchange, dust handling, a mature cement plant, and complex ground conditions, all described in more detail in HM[9]. Such factors contribute to high uncertainty but also offer significant potential for learning and development over time.

Transport ships are rated yellow, indicating that the technology in this segment has some cost-reduction potential. NL's ships are built as "dual-purpose" vessels, meeting class requirements for transporting both CO_2 and LPG. It is expected that ships purpose-built for CO_2 transport could offer cost-saving solutions.

The NL receiving terminal and the permanent storage site are also rated yellow, indicating moderate maturity and probably less room for cost reduction. Although certain components still require customization, experience from storage projects like Snøhvit and Sleipner may help reduce risk and support further development.

Supplier-market maturity: Is there a functioning supplier market?

The supplier market for capture, compression, and intermediate storage seems to have the greatest potential for cost reduction. This reflects a limited number of players and a relatively extensive use of FOAK solutions, which can lead to uncertainty regarding scalability and cost-efficiency.

Integration is rated yellow, indicating a moderately functioning market. While there are several suppliers, challenges exist with complex interfaces between actors, potentially leading to delays and increased costs. Nevertheless, established players can contribute to development and competition. The permanent storage site faces similar interface challenges, although established suppliers also support development.

Ship transport has a well-established international market with multiple providers offering competitive solutions, reducing risks and lowering costs. The NL receiving terminal has commercially developed solutions available and is also rated green.

CCS-specific procurement expertise: Does the procurer have relevant experience when entering contracts?

There appears to be considerable potential for cost reductions by increasing procurement expertise among emission operators before entering contracts for capture, compression, and intermediate storage. HM had limited knowledge as a buyer of a full-scale capture plant. Their focus was on technical performance based on pilot experience. Limited consideration was given to what a full-scale project entails in terms of scope, standards, supplier execution methodology, and change management.

Regarding integration work, HM had good knowledge and experience in procuring from suppliers. The yellow rating here stems from underestimating the size and complexity of the total project, which required different suppliers/work packages to coordinate in a large-scale effort. The Øygarden terminal is also rated yellow – even though NL JV, led by Equinor, is an experienced buyer in large projects – due to insufficient consideration that suppliers lacked experience with CO_2 facilities.

Transport ships are rated green, as NLJV (Shell) used standard procurement methodology and accounted for several potential cost-driving elements, such as currency hedging. For storage, no significant cost-reduction potential was identified, as NLJV (Equinor) possesses strong procurement competence in this area.

Appropriate contract models: Do contracts have clear, relevant specifications and balanced terms that incentivize cost-effective solutions?

There are moderate challenges related to the contracts for integration and for capture, compression, and intermediate storage. Contracts are often based on offshore specifications, which may be unnecessarily detailed and thus increase costs. Limited insight and many FOAK solutions complicate efforts to ensure cost-efficiency. The project is defined as brownfield, meaning significant work is expected on existing facilities. This leads to complex interfaces and combines with the lack of specification requirements from HM, makes achieving cost savings difficult. Brownfield projects may present more unforeseen challenges than greenfield projects, which are built from scratch, increasing project risk due to difficulties in predicting and managing issues in existing structures.

The contract design for transport ships, the NL receiving terminal, and the permanent storage site appears to have low potential for cost reductions. Ship transport is secured through fixed-price contracts protecting against material price changes (e.g., steel) and currency fluctuations, reducing cost risk. The storage site is also well secured contractually, despite challenges like tunnel collapses that led to increased investment costs. These issues were managed effectively through sound contracts.

Regulatory maturity: Do current regulations and frameworks create unwanted costs in the chain?

The regulatory and framework analysis for the CO_2 value chain shows that the storage site faces the most significant challenges regarding undesirable costs. Several critical uncertainties exist concerning long-term responsibility for monitoring and leakage handling, and how this should be defined and allocated.

Integration, capture, conditioning, and intermediate storage all face moderate cost challenges due to regulations that may drive unnecessary costs. This may stem from suppliers applying standards based on offshore regulations that are not strictly required. Another relevant factor when implementing CO_2 capture plants in existing factories is the need to modify existing equipment. This may trigger changes due to current regulatory requirements. At Brevik CCS, for example, existing wind load calculations and associated requirements led to increased costs for a cooling tower that had to be completely modified.

Ship transport and the Øygarden receiving terminal also face moderate challenges, as most regulations are covered. However, more specific requirements related to CO_2 handling are still needed. These cost challenges are nevertheless considered moderate compared to those of the storage site. One example is CO_2 tanks equipped with lightning conductors – a standard for oil tanks due to explosion hazards from flammable liquids. CO_2 behaves more like a fire suppressant, making such measures unnecessary and resulting in extra costs without contributing to increased safety.

CCS-adapted industrial practice: Are appropriate standards and industrial practices used in the CCS value chain?

An analysis of standards and established industrial practices used in Longship shows significant variation. For the capture plant at Brevik CCS and at the Øygarden receiving terminal, there appears to be great potential for cost reductions. The main supplier used methods and standards from the offshore oil and gas sector, resulting in solutions and material choices that may be unnecessarily expensive for land-based industry needs. Knowledge sharing from NL has highlighted several examples of areas and solutions with cost-reduction potential.

The permanent geological storage site uses established offshore and subsea standards. Although costly, these are likely closer to the necessary standards for CCS. Brand-new solutions and standards for CCS-adapted injection wells may offer some cost savings.

At Brevik CCS, land-based industrial practice has largely been applied by the suppliers and is considered to offer low cost-reduction potential. Many of the contractors are local companies familiar with delivering to land-based industries. For ships, maritime standards have been used according to class requirements. The CO_2 tanks are the only major components that deviate from established standards. However, there is not considered to be significant cost-reduction potential related to the ships.

Economy of scale: Is there a cost advantage handling larger volumes in each element of the chain?

In the analysis of economies of scale, each cost driver element in the Longship value chain is assessed for its potential to handle larger volumes. It is not assumed that every element across the value chain must handle the same volume.

The establishment costs for the geological storage site in Longship are expected to have the greatest potential for significant cost reductions per tonne of CO_2 stored as the total stored volume increases. The pipeline capacity from Øygarden to the storage site is 5 million tpa CO_2. This capacity is intended to be utilized when more customers deliver CO_2 to the storage site.

A medium cost-reduction potential per tonne is estimated for the four elements: integration, capture, transport, and the receiving terminal. Once the current capture plant is in operation, the operations team will become familiar with the facility, and various bottlenecks are expected to emerge. These can form the basis for changes if HM wishes to capture more CO_2 from its own emissions in the future. Some infrastructure and groundwork can likely be reused without significant additional costs.

CO_2 will be transported by ships operating at about 70% of their capacity. There is room for additional volume from HM. Improved coordination with other customers may also enhance logistics chain utilization. The receiving terminal and pipeline to the permanent storage site have expansion potential, and increasing capacity could make better use of the initial investments.

5. Potential for Cost Reductions in the CCS Value Chain

Analyses from Longship indicate significant potential for cost reduction in the further development of CCS facilities.

The expected overall investment costs are distributed as percentages across the five main elements of a mass-balanced CCS value chain in Figure 7.

In such a chain, it is expected that well over half of the investments will be allocated to the construction of facilities for capture, compression, and intermediate storage, as well as integration with the emission sources.

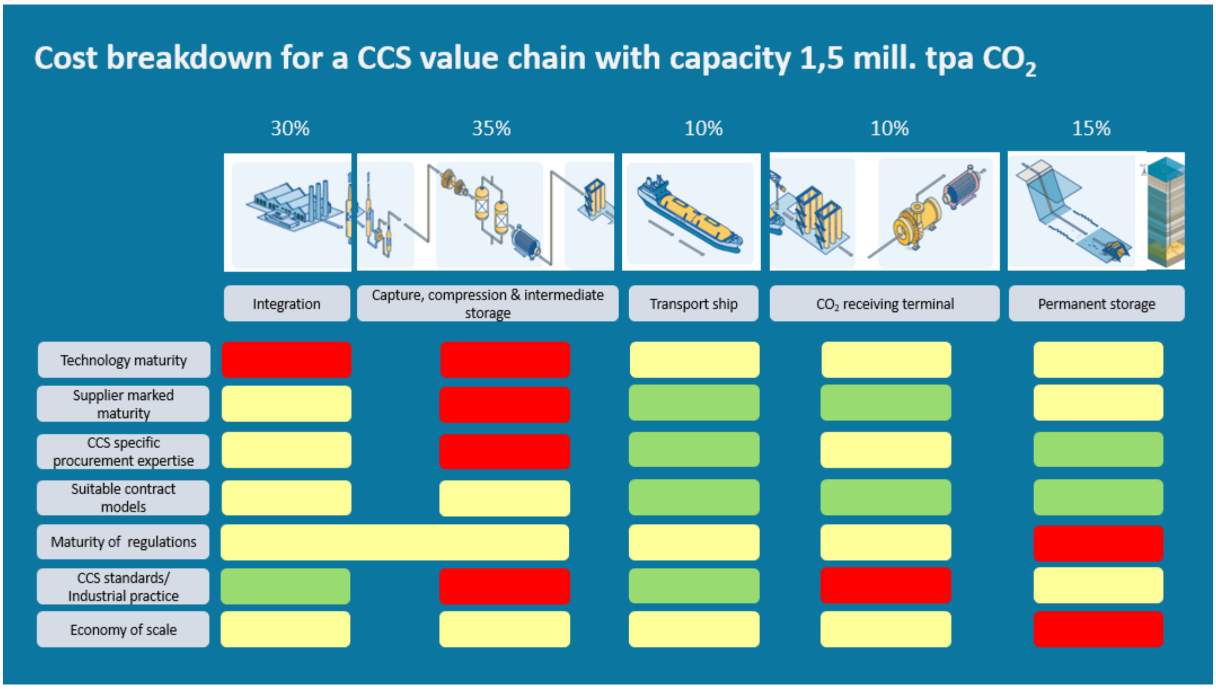

Figure 7 Potential for cost reductions in a CCS value chain with a capacity of 1.5 million tpa of CO_2.

CO_2 capture, compression, and intermediate storage, as well as integration with emission sources, represent a significant share of the investment costs in a mass-balanced CCS value chain, as shown in Figure 7 Potential for cost reductions in a CCS value chain with a capacity of 1.5 million tpa of CO_2. These are likely the parts of the CCS chain that will have the strongest replication potential for future projects. Here, there is substantial potential to identify cost-reducing measures that others can benefit from. This is also the part of the CCS value chain that received the reddest markings in the various thematic sections of the traffic light analysis.

The receiving terminal and the permanent storage site are expected to account for around one-quarter of the costs in a mass-balanced CCS value chain. This part also has cost reduction potential in future projects. By nature, there will be fewer CO_2 terminals/storage sites than capture facilities, and therefore fewer actors who can benefit from the experience. A more targeted dialogue is recommended with relevant projects that may benefit from Longship's experience.

Qualitative assessment of cost drivers

Technology maturity received the highest number of red and yellow indicators in the traffic light analysis. The CCS value chain is characterized by many FOAK (First-of-a-Kind) solutions, and the choice of technological solutions carries considerable potential for cost reductions. This also applies to decisions concerning the integration between the emission source and the selected capture technology.

Regulatory maturity did not receive any green indicators in the analysis and is still considered immature from a CCS perspective. Experiences from Longship will contribute to the development of more cost-reducing and CCS-adapted regulations, along with relevant guidelines and interpretations.

CCS-adapted industrial practice received red indicators in the traffic light analysis, both for the capture process and the receiving terminal. These components – together making up nearly half of the costs in the value chain – are expected to offer significant potential for cost reductions. Industrial practice is closely linked to both technology and regulation. The learning reports from the Longship actors are valuable sources for unlocking this potential.

6. Conclusion

Cost reductions are essential for CCS to play a significant role in reducing global carbon emissions. Longship provides valuable insight in this area.

Gassnova's analysis show that the supplier market for the capture process needs to be strengthened with knowledge of CCS-adapted practices and standards from land-based industry to enable more cost-effective solutions. At the same time, procurement competence at emitters needs better alignment with CO_2 handling technologies. There is also potential for cost reductions at receiving terminals by leveraging experience from land-based construction practices and industrial standards more effectively, as well as through tailored CCS regulations. For permanent offshore CO_2 storage, it is important to establish regulatory frameworks that clearly define responsibility for the stored volumes.

Scaling capacity up to 1.5 million tonnes of CO_2 per annum across the entire value chain shows that capture processes account for the largest share of investment costs. This highlights the need to prioritize the development of technological maturity for capture facilities, along with the integration conditions with emission sources.

In summary, this report, *"Based on Longship: Potential for Cost Reductions in the CCS Chain"*, highlights the most important cost drivers in the CCS value chain as of November 2024. Several of the areas identified in this report are expected to be subject to more in-depth analyses going forward.

7. Abbreviations and Definitions

Term	Definition
Brevik CCS	Heidelberg Materials' CO_2 capture project from the cement production facility in Brevik
Brownfield	An existing industrial area or facility that is upgraded or repurposed, in contrast to building new on a greenfield site
CCS	Carbon Capture and Storage – a process to capture, transport, and store CO_2 permanently underground to reduce emissions
ED	Ministry of Energy – The government ministry responsible for energy policy, including projects related to renewable energy and carbon capture
FEED	Front-End Engineering Design – A study conducted early in a project to define technical solutions and cost estimates for detailed design
FOAK	First-of-a-kind – A designation for the first implementation of a new technology or solution, often associated with greater uncertainty and higher risk
Greenfield	A new project or facility built from scratch on a greenfield site without prior development, in contrast to a brownfield project reusing existing assets
HM	Heidelberg Materials – A global company producing building materials, including cement, and involved in carbon capture and storage
KS2	Quality Assurance Level 2 – A quality assurance process for major public investment projects, conducted prior to final approval and implementation
LNG	Liquefied Natural Gas
NL	Northern Lights – The CO_2 storage project under Longship, which transports, temporarily stores, and permanently stores captured CO_2 under the seabed in the North Sea
NLJV	Northern Lights Joint Venture – The Northern Lights project, operated by the companies Equinor, Shell, and TotalEnergies in partnership
Oslo CCS	Hafslund Celsio's CO_2 capture project from the waste-to-energy plant at Klemetsrud
CCS glossary	See also this page for more CCS-related terms and expressions

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